J-PARC P02 PROJECT:"THE STUDY OF EXOTIC MULTIQUARK STATES IN SYSTEMS WITH Λ-HYPERONS, K_S^0-MESONS AND γ - QUANTA "

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Abstract. The designed 2m propane bubble chambers(PBC) with modern power technologies for PC and high precision digital photographic methods is a unique multi-propose, competitive capable and higher-informative 4π detector for study of exotic multi-strange events with $V^0(\Lambda, K_s^0$ and $\gamma)$ particles, light hyper-nucleus, (V^0, V^0) interactions and other correlations (P02 J-PARC LOI). The designed PBC will provide on line data measurement and data taking more than 100 times faster(or $> 10^7$ events/year) than old CERN-HPD system. First from all of unbeatable privilege for PBC are registration of multi-vertex or complex decay modes(with 10-50μm space resolution), where is included of the beam area too. The acceptance of beam area for detectors is crucial important for Λ hyperon physics, because more than 70% from Λ hyperons are emitted in the beam area with azimuth β or polar angles $< 15^0$ in p+C reaction at 10 GeV/c.

Strange multibaryon states with Λ- hyperon and K_s^0 meson subsystems has been studied by using data from 700000 stereo photographs or 10^6 inelastic interactions which was obtained from expose 2-m propane bubble chamber LHEP, JINR to proton beams at 10 GeV/c. The observed well-known resonances Σ^0, $\Sigma^{*\pm}(1385)$ and $K^{*\pm}(892)$ from PDG are good tests of this method. The subject of proposed P02 project allow to explore of multi-strangeness in hadronic systems with V^0 particles what are also included as P05,P07,P18, p22 and p027 approved experiments by a missing mass method at J-PARC. New developed research complexes NUCLATRON-M at JINR and J-PARC at JAEA(KEK) on base of progress in digital technology for BC experimental method allow to obtain of a necessary statistics in reasonable time, what inspire the optimism for establish exotic states with Λ and K_s^0 particles, which were observed more than 30 year historical periods from different old experiments with a poor statistics. Only with high statistics or from many similarly old photographs without new necessary acceptance, resolution and methods analysis there will not possible to obtain of new information about these objects.

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Welcome to collaboration.

2. Scientific goals and scientific merits

2.1. **Scientific goals.**

Multi- quark states, glueballs and hybrids have been searched for experimentally for a very long time[1],[2], but none is established. The PBC method allow to study of the following actual problems: in-medium modification of strange hadrons, the origin of hadron masses, the restoration of chiral symmetry, the confinement of quarks in hadrons, the properties of cold dense baryonic matter and nonperturbative QCD, Λ yields and the structure of neutron stars.

Exotic strange multibaryon states have been observed in the effective mass spectra of: $\Lambda\pi^{\pm}$, Λp, Λpp, $\Lambda p\pi$,$\Lambda\Lambda$ and ΛK^0_S, K^0_Sp, $K^0_S\pi^{\pm}$ subsystems.The experimental data from the 2-m propane bubble chamber for systems with Λ and K^0_s states have been analyzed in detail in reports [11]$-$[14].

Strange multi-strange clusters are an exiting possibility to explore the properties of cold dense baryonic matter [3, 5]. Although such states were predicted by Wycech earlier, but only recently the availability of experimental facilities as E471(KEK), FOPI(GSI), FINUDA(INFN), OBELIX(CERN) and DISTO has observed. In particular for studying these kind of exotic nuclei, has delivered first experimental results which triggered a vivid discussion and project of AMADEUS, INFN. Following [4], we assume that the above experimental fact is due to the formation of a 'blob' of QGP. A recent paper over viewing the status of the problem, from A. Gal [5]: It is clear that the issue of $\overline{K}^0$ nuclear states is far yet from being experimentally resolved and more dedicated, systematic searches are necessary.

The problems on the interaction between hyperons and nucleons have been poor studied until today. At the same time the study of the processes of elastic dispersion hyperons+N yields much information on the nature of hyperons and the character

of hyperon-nucleonic, hyperon - nucleus and hyperon-hyperon forces. Non-elastic processes, such as $\Lambda + p \rightarrow \Sigma^+ N$ are also interesting. The study of YN scattering offers a unique way of probing the short range behavior of Baryon-Baryon interactions due to the added degree of freedom, the strangeness.

The study a Ericson fluctuations for Λ hyperons, γ quanta and protons momenta in backward direction, because the character of deviations of experimental spectra from "smooth" theoretical curve predicted within the framework of the fireball model of cumulative effect [6],[7].

At present the experimental situation is confused; so is theory. So too is the complete absence of exotic mesons, and, except for the recent discoveries, of exotic baryons as well.The classic example is a baryon with positive strangeness, a Z^+ as it is known, with valence quark content uudd$\overline{s}$. The designed bubble chamber as a new competitive technique will allow in the study of multistrange states with V^0 particles.Because only with high statistics or from many similarly old photographs without new necessary acceptance, resolution and methods analysis there will not possible to obtain of new information about these objects.

2.2. **Scientific merits.**

2.3. **The propane bubble chamber.**

PBC method is the most suitable, higher-informative and multi-propose 4π detector(included beam range too) for study of exotic multi-vertex states with V^0 particles [8],[13]. The average geometrical weights for Λ, K_s^0 and γ are to 1.34, 1.22 and 4.1 in p+propane collision at momentum 10 GeV/c, respectively. The average effective mass resolution of (V^0, V^0),(V^0,stoping particles) system is equal to 0.5-1.0 %. A low beam intensity (15-20)particles/spill can particularly compensate by using of large chambers (as 2m PBC), large cross sections (p+propane 1450 mb, dead time is to 5 sec, 5 events/spill), fast cyclic chambers, secondary relativistic beams from Λ, Ξ^- hyperons and K^+, K^-, K_l^0-mesons.

The GEOFIT based on the Grind-CERN program is used to measure the kinematic parameters of tracks: momentum(P), tgα(α - depth angle) and azimuthal angle(β) from the stereo photographs. The momentum(P) of resolution and the average track length (L) for charged particles are to ΔP/P=2%,$< L >$ =12 cm for stopped particles and ΔP/P=10 %, $< L >$ = 36 cm for nonstopped particles. The momentum resolution of V^0 from (1V-3C) fit is to ΔP/P= 2the depth and azimuthal angles are to Δtgα = 0.0099 (0.6^o) $\pm$ 0.0002 and β = 0.0052 $(0.3^o)\pm$ 0.0001 (rad.).

The estimation of ionization, the peculiarities of the end track points of the stopped particles, allowed one to identify them. Protons, $K^{\pm}$ and $\pi^{\pm}$ can exactly identified by ionization over the following momentum range: 0.13$< P_p <$0.9 GeV/c, 0.05$< P_K <$0.6 GeV/c and 0.025$< P_\pi <$ 0.3 GeV/c. Protons can separate from other particles in the momentum range of $P_p <$ 0.9 GeV/c .

Figure 1 shows basic experimental and simulation by FRITIOF model distributions of Λ - hyperons in p+propane interaction at 10 GeV/c. There are satisfactory description by the polar angle (Θ_Λ) and d) by the azimuthal angle β. But FRITIOF model did not describe of the momentum (p_Λ) and the transverse momentum (p_Λ^t) distributions. There are observed fluctuations by momentum in ranges of 1.56(4σ),1.9(3.5σ) and 2.15(3σ)GeV/c. Then observed fluctuations by

azimuthal β angle (3σ) in ranges of -0.7^o and -6.8^o (preliminary) has shown in Figure 1,d. More than 70% from Λ hyperons are emitted of beam area with azimuth or polar angles $<$ 15^o in p+C reaction at 10 GeV/c(Figure 1c,d).

The $\Lambda\pi^+$ effective mass distribution for all 19534 combinations with bin size 12 MeV/c^2 has shown in Fig.2a. Fig.2b with cut of $p_{\pi^+} <$ 1GeV/c shown, where is removed background from protons. This observed resonance identified as $\Sigma^{*+}(1382) \rightarrow \Lambda\pi^+$ with similar decay properties as in PDG data which was a good test of this method.The $\Lambda\pi^-$- effective mass distribution for all 6465 combinations with bin sizes of 14 and 8 MeV/c^2 in Fig.2(c,d) are shown. The width for Σ^{*-} observed $\approx$2 times larger than PDG value(Fig.2,c). The peak in mass range of M(1370) is decayed into three ranges:M(1317)+M(1360)+M(1385)(Fig.2,d). Where M(1317)and M(1385) can interpreted as contributions from Ξ^- and $\Sigma^{*-}(1385)$. Then M(1360) peak can interpreted as contribution from phase space or medium effect with $\Sigma^{*-}(1385)$ in carbon nucleus.

2.4. **On line data taking and analysis from digital stereo photographs.** This bubble chamber method was closed because there were two defects. First defect is low beam intensity (15-20)particles/spill(more 1 inter./sec) which is particulary can to compensate by using large length chambers as 2m PBC, large cross sections($\sigma_{p+propane} \geq$1450 mb) , fast cyclic chambers, parasitic and secondary exotic beams from Ξ^-, Λ hyperons and K^-, K_l^0-mesons. Second defect is slow data measurement and daq by using human eyes what now is removed because the development of digital photographic technology came up to higher precision which is suitable for a bubble sizes($\approx$ 10-50 micron). Computers have evolved from large mainframes to desktop and laptops with computing power several orders of magnitude larger than what was available some decades ago. The designed bubble chamber detector with digital photographic stereo cameras by using of software on base of CERN-HPD for reconstruction and automatic analysis of stereo pictures what will provide on line data taking and measurements more 100 times faster(or 10^7 events/year) than allowed old HPD method. Automatic data taking software had been developed for CHORUS, E373,E07 and OPERA experiments as a hybrid emulsion methods.

Main task of project will improve of the automatic on line data taking and reconstruction software for bubble chamber methods on base of obtained experience for digitized technologies from different experiments in last years. A estimation with 2 μm space resolutions from one projection of scanned stereo picture is equal to $\approx$100 mb space in hard disc. Figure 3 shows the "minimum guide" sketch of automatic on line and off line data taking and measurement system flow chart from BC directly on base of HPD CERN[9].

2.5. **DAQ - PBC experiment.** Beam momentum: 10 (or 12) GeV/c protons
Intensity as parasitic beam by using of bent crystal method: 15-20 protons/circle)
Spill interval: 5 sec/circle and 1 inter. per sec.
p+C_3H_8 (inelastic interactions)/day:(>) 72000
(inelastic interactions from secondary particles)/day:(>) 65000(2100 Tb)
Beam time: 100 day for setup
Total number inelastic interaction from beam protons :7.2$\times 10^6$
Target: C_3H_8 propane , 200cm length ,0.43 g/cm^2 density
Estimated Yield: the number of identified $\Lambda(\rightarrow \pi^- p)$ hyperons $\geq$ 63000(40Tb) and

Stages	1 year	2 year	3 year	4 year	5 year
phase 1	×	×	×	-	-
phase 2	-	×	×	×	×
phase 3	-	×	×	×	×

TABLE 1. Timetable for stages of proposal

$\Sigma^0(\to(\Lambda\gamma)\geq 2000$
Number of $K_s^0(\to\pi^-\pi^+)$ mesons ≥ 30000(20 Tb)
Statistical significance of reviewed peaks in proposal p02 will increase 4(5) times.

2.6. **The proposed stages of proposal.** Phase-1: organize collaboration; select main physics tasks and reaction topology , inspect of old detector; discuss and develop of type, size and cost for universal super conducting magnet; minimum guide program debug on base of ROOT; manpower -7; estimate of exactly budget for phase-1 and phase-2(≈ 370kUSD for PBC without magnet, 3 year), the budget for phase-1 is 37kUSD in 1 year.

Phase-2: design a proposed location , prepare CDR for PBC without magnet(Fig. 3) , prepare CDR for parasitic beam formation with bent crystal; develop and debug simulation and reconstruction software on base of ROOT-GEANT4, install of minimum guide and 0 guide programs, construct of PBC without magnet, construct and install of gas and other necessary systems, construct and install of PBC with digital stereo photographic system;; , manpower 13; CDR for universal super conducting magnet; prepare total CDR for PBC with magnet;

Phase-3: construct and install parasitic beam extraction by bent crystal method, construct of universal magnet, construct and install of PBC with magnet, construct and install trigger, install data taking, test experiment for installation of detector(3 year).

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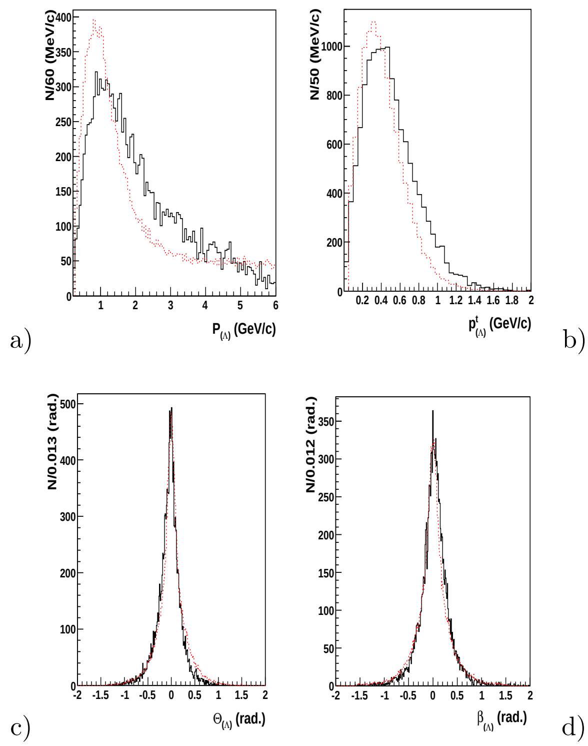


FIGURE 1. Experimental(solid) and simulation by FRITIOF model(dashed) distributions of Λ - hyperons in p+propane interaction at 10 GeV/c: a)by the momentum (p_Λ); b) by the transverse momentum (p^t_Λ); c) by the polar angle (Θ_Λ); d) by the azimuthal angle β.

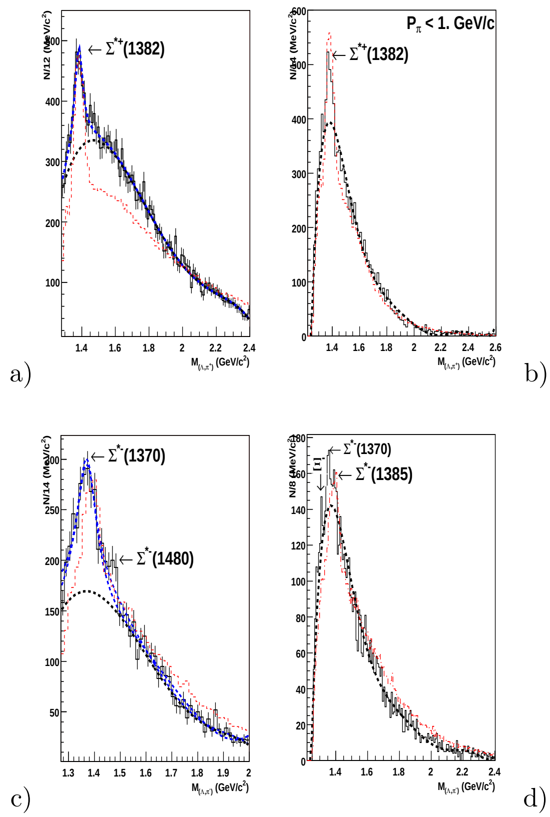
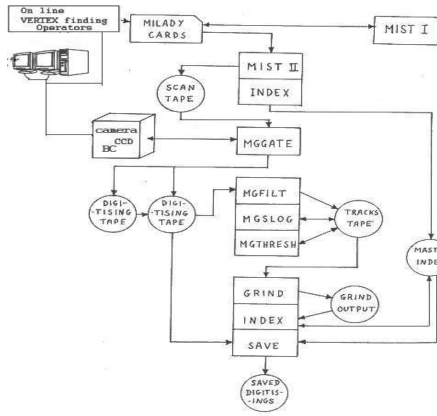
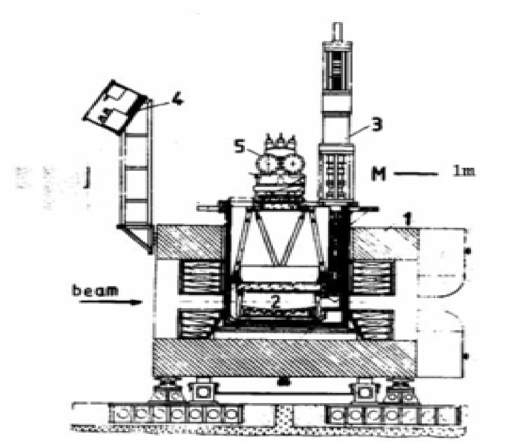


FIGURE 2. *a)The $\Lambda\pi^+$ - spectrum for all combinations with bin size of 12 MeV/c^2 b) $\Lambda\pi^+$ - spectrum in momentum range of $P_\pi <$ 1 GeV/c with bin size of 14 MeV/c^2; c) $\Lambda\pi^-$ spectrum for all combinations with bin size of 14 MeV/c^2;d)$\Lambda\pi^-$ spectrum for all combinations with bin size of 8 MeV/c^2. The simulated events by FRITIOF is the dashed histogram. The background is the dashed curve.*



a)



b)

FIGURE 3. a)The sketch of automatic on line and off line data taking and measurement system flow chart on base of Minimum Guidance system for CERN HBC[9]. b)The frontal view of HBC,JINR, where 1 is a universal magnet as a barrel; 2 is chamber; 3 is mechanism of the expansion[10].